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ORIGINAL ARTICLE

# Alteration in cervical spine mechanics in obstructive sleep apnea syndrome patients

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**KEYWORDS**

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**Abstract** *Background:* Obstructive sleep apnea syndrome (OSAS) is a multi-factorial disease with many identified risk factors and mechanisms. Little research exists on cervical spine mechanics as a risk factor for OSAS.

*Objectives:* This study aimed to explore the association and predictive value of alterations in cervical spine mechanics with the severity and positional dependency in patients with OSAS.

*Methods:* After patient consent and IRB approval, 36 consecutively admitted adult patients (68.1% were males), aged 46 years, who underwent clinical evaluation and standard polysomnography were included in this cross-sectional study. Severity scores were estimated from a full night polysomnography sleep study (apnea hypopnea index (AHI), respiratory disturbance index (RDI), desaturation index, overall severity score, snoring index and episodes). Positional dependency for all severity scores was performed. Cervical spine X-rays (PA and lateral) were performed to measure the atlas angle (relative to the horizontal plane) and Cobb angle (a standard measurement for lordosis), the pre-vertebral soft tissue and pharyngeal air column diameter were measured.

*Results:* Median BMI (32.63) and sleep apnea indices were high with severe AHI (>30). Positional dependency (63.9%) was significant for RDI. Both the Cobb and atlas angles showed a significantly negative correlation with severity indices and positional dependency. The Cobb angle of lordosis (but not the atlas angle) was a significant negative predictor for all OSAS severity, snoring index and positional dependency.

*Conclusion:* In OSAS patients, there was a significant association between alterations in cervical spine mechanics, severity and positional dependency. Cervical lordosis, but not the atlas angle, was

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a significant negative predictor of severity and positional dependency. Further studies are needed to validate these results and to study the effect of improving spinal curvature and angular rotation on severity and positional dependency in OSAS patients.



## Introduction

Obstructive sleep apnea syndrome (OSAS) is a disorder that is characterized by obstructive apneas and hypopneas caused by repetitive collapse of the upper airway during sleep. OSAS is a common chronic disorder that often requires lifelong care [1]. One-third of sleep studies in the general adult population show some degree of OSAS [2]. Among adults 30–70 years of age, approximately 13% of men and 6% of women have moderate to severe forms of OSA. Approximately 25% of adults are at risk for some degree of sleep apnea [3]. Over time, OSAS can be a serious disorder with increased risk for poor neurocognitive performance that could impact daily activities and long-term health [2].

The underlying pathophysiology of OSA is multifactorial and may vary considerably between individuals. The important risk factors for OSA are advancing age, male gender, obesity, and craniofacial or upper airway soft tissue abnormalities. Additional risk factors include smoking, nasal congestion, menopause, and family history [4]. The rates of OSAS are also increased in association with certain medical conditions, such as pregnancy, end-stage renal disease, congestive heart failure, chronic lung disease, and stroke. The severity of OSAS in any given individual is influenced by other factors as well, including upper airway anatomy, arousal threshold, upper airway muscle drive, and stability of the respiratory control system. In addition, the underlying pathophysiology may vary by age, as younger patients are more likely to have alterations in ventilatory control and older patients are more likely to have predominant upper airway collapsibility [5,6].

The cervical spine is one structure that may contribute to OSAS with some reported association with specific cervical column pathologies, such as osteochondromas [7] osteophytes [8], and rheumatoid arthritis [9]. Two studies [4,10] found a higher prevalence of morphological spinal deviations in patients with sleep apnea (46% and 43%, endogenous fusions predominantly) than in control subjects (14%). The spinal abnormalities may be explained by two well-known predisposing OSAS factors: craniofacial features and extended head posture. The latter represents a physiological adaptation to maintaining airway patency [11]. Another study [12] found a predominant upper cervical kyphotic spine and occiput among OSAS patients, with the greatest extent of flexion in the most severe OSAS patients.

Loss of cervical spine curvature and alteration in the atlas angle may change our understanding of OSAS pathophysiology in adults and highlight the potential mechanisms underlying this new risk factor that may modulate disease severity. However, there are still only a few investigations aimed at understanding the association, correlation, or the predictive value of altered cervical mechanics in patients with OSAS. Therefore, this study was performed to explore the association and predictive value of alterations in cervical spine mechanics in patients with OSAS.

## Methods

### *Participants*

We studied 36 consecutively admitted patients to the "Saudi German Hospital Sleep Center" with confirmed OSAS. All subjects underwent an overnight in-laboratory standard polysomnography study. All sleep studies were scored in a blinded fashion and interpreted by an experienced pulmonary and sleep physician. The polysomnographic data used in this study were extracted from overnight sleep studies. Sleep studies of patients who slept less than 6 h with sleep efficiencies less than 90% were subjected to another night sleep study. The sleep architectures and apneas/hypopneas were scored according to the manual of American Academy of Sleep Medicine, version 2.0 2012 [13]. The AHI is calculated by dividing the number of apnea events plus hypopnea events by the number of hours of sleep. OSAS was defined by an apnea hypopnea index (AHI) $\geqslant 5$ events/h of sleep. AHI values were used to categorize OSAS severity as follows: normal: 0–4; mild: 5–14; moderate: 15–29; and severe: 30 or more [14]. The respiratory disturbance index (RDI) was used to measure the number of recorded apneas, hypopneas, and respiratory effort-related arousals per hour of sleep during the PSG evaluation. The oxygen desaturation index (ODI) was defined as the average number of oxygen desaturations of 4% or more per sleeping hour [15]. The overall sleep apnea severity score was calculated by combining AHI and oxygen desaturation to evaluate both the number of sleep disruptions and the degree of oxygen desaturation. Patients were diagnosed according to the Centers for Medicare & Medicaid Services criteria for the positive diagnosis and treatment of obstructive sleep apnea [16]. A positive OSAS test is established if either of the following criteria using the AHI or the RDI is met: AHI or RDI greater than or equal to 15 events per hour or AHI or RDI greater than or equal to 5 and less than or equal to 14 events per hour in combination with documented symptoms of excessive daytime sleepiness, impaired cognition, mood disorders, insomnia, or documented hypertension, ischemic heart disease, or history of stroke.

Patients were excluded if they had a history of stroke with severe disability or a previous history of spinal surgery or traumas. The protocol was approved by the local "Scientific Review Committee of Research," and informed consent was obtained from all participants. Prior to admission, all participants underwent a detailed history and physical examination, including anthropometric measurements.

Positional AHI dependency, RDI, desaturation index, and snoring. Positional dependency in patients with OSAS was defined as a supine index greater than or equal to twice the non-supine index. Cervical spine X-rays (PA and lateral) were performed to measure the atlas angle (relative to the horizontal plane), Cobb angle (a standard measurement for lordosis), the pre-vertebral soft tissue and pharyngeal air column diameter. Lateral radiographs were taken by a licensed X-ray laboratory following standard techniques before any clinical interventions were performed. The cervical angles were assigned following the standard kinematic nomenclature for physiologic accelerations in a right handed coordinate system [17].

*Statistical analysis*

The data analysis was performed using the Statistical Package for the Social Sciences software program version 20 (SPSS Inc., Chicago, IL). Descriptive data are expressed as medians (due to their abnormal distribution) for continuous variables and percentages for proportions. The comparative statistical analysis was performed using the chi square Friedman Test of related samples for positional dependency. Bivariate Pearson correlations and scatter plots were used for associations. Linear regression analysis was performed for multivariate regression analysis. The statistical tests were two-tailed, and a value of $p < 0.05$ was considered to be the cut-off value of significance.

## Results

This cross-sectional study included 36 patients with OSAS, mostly males (86.1%). The median age was 46 years and BMI was high (32.63), in the range of obesity. The sleep apnea indices were also high, and the median AHI was severe (> 30) with 11% mild, 22.2% moderate and 66.7% severe (Table 1). Snoring frequency was non-significantly higher in the supine position than in the lateral position, with 33.3% of cases demonstrating positional dependency. RDI was significantly higher in the supine position than in the lateral position, with 63.9% of cases demonstrating positional dependency (Table 2).

**Table 1** Demographic, anthropometric, sleep and snoring data in patients with OSAS ($n = 36$).

| | $n = 36$ | Median |
|---|---|---|
| Demographic data | Gender: $n$ (%) | |
| | Females | 5 (13.9) |
| | Males | 31 (86.1) |
| | Age: years | 46.00 |
| Anthropometric data | Height: cm | 170.00 |
| | Weight: kg | 93.00 |
| | BMI: kg/m$^2$ | 32.6300 |
| Severity of sleep apnea indices | Apnea hypopnea index (events h$^{-1}$) | 35.700 (severe) |
| | Mild: $n$ (%) | 4 (11) |
| | Moderate: $n$ (%) | 8 (22.2) |
| | Severe: $n$ (%) | 24 (66.7) |
| | Respiratory disturbance index | 36.600 |
| | Desaturation | 44.000 |
| | Overall severity score | 80.7000 |
| Snoring | Snoring index | 313.800 |
| | Snoring episode | 87.30 |
| Cervical curve angles | Cobb | 34.00 |
| | Atlas angles | 22.90 |
| Cervical region | Paravertebral tissue | 0.4900 |
| | Airway column | 1 |

**Table 2** Positional dependency of the RDI and snoring.

| | Position | Index | $p$ |
|---|---|---|---|
| RDI | Supine | 47.700 | 0.000 |
| | Left | 16.60 | |
| | Right | 12.200 | |
| | Supine/lateral $\geqslant$ 2: $n$ (%) | 23 (63.9) | |
| Snoring index | Supine | 320.600 | 0.091 |
| | Left | 177.50 | |
| | Right | 214.00 | |
| | Supine/lateral $\geqslant$ 2: $n$ (%) | 12 (33.3%) | |

Both the atlas angle and cervical Cobb angle of lordosis correlated negatively with BMI ($r = -0.760$ and $r = -0.774$), ($p = 0.000$ for all), the 3 OSAS severity indices (AHI, RDI, & desaturation index) (Figs. 1 and 2) and the overall severity score ($r = -0.465$, ($p = 0.004$) and $r = -0.717$, ($p = 0.000$), respectively).

While the Cobb angle correlated with male gender ($r = 0.350$, $p = 0.037$), the atlas angle correlated negatively with age ($r = -0.531$, $p = 0.001$). The atlas angle but not the Cobb angle correlated negatively with the snoring index ($r = -0.526$, $p = 0.001$) (Table 3). Linear regression analysis showed that the 2 angles explained more than 50% of the variability in the overall severity index ($R^2 = 0.523$, $F = 18.072$, $p = 0.000$). Similarly, the 2 angles explained more than 40% of the variability in the RDI positional dependency ($R^2 = 0.411$, $F = 11.411$, $p = 0.000$). Only the Cobb angle was a significant negative predictor of the 3 severity indices (AHI, RDI, and desaturation index) and the overall severity score (Beta = −0.818, $p = 0.000$) (Table 4). Similarly, the Cobb angle was a significant negative predictor for both snoring and RDI positional dependency (Beta = −0.634, $p = 0.006$ for snoring and Beta = −0.734, $p = 0.001$ for RDI) (Table 4).

## Discussion

The current study included OSAS cases with high median severity scores and BMI. The study population was an adequate representation of OSAS patients, as the disease predominantly affects males and is usually associated with obesity [18]. This study represents one of the few studies that addressed cervical spine alterations in OSAS patients. The results show that both spinal angles (the Cobb and atlas angles) had a significant negative correlation with severity indices and positional dependency among OSAS patients (Table 3). Moreover, the Cobb angle of lordosis (but not the atlas angle) was a significant negative predictor for all OSAS severities, the snoring index and positional dependency.

A regression analysis in the present study gave an estimation of the contribution of spinal mechanics to the overall OSAS severity and positional dependency through the $R^2$ values (Table 4). Both angles could substantially explain 52% of

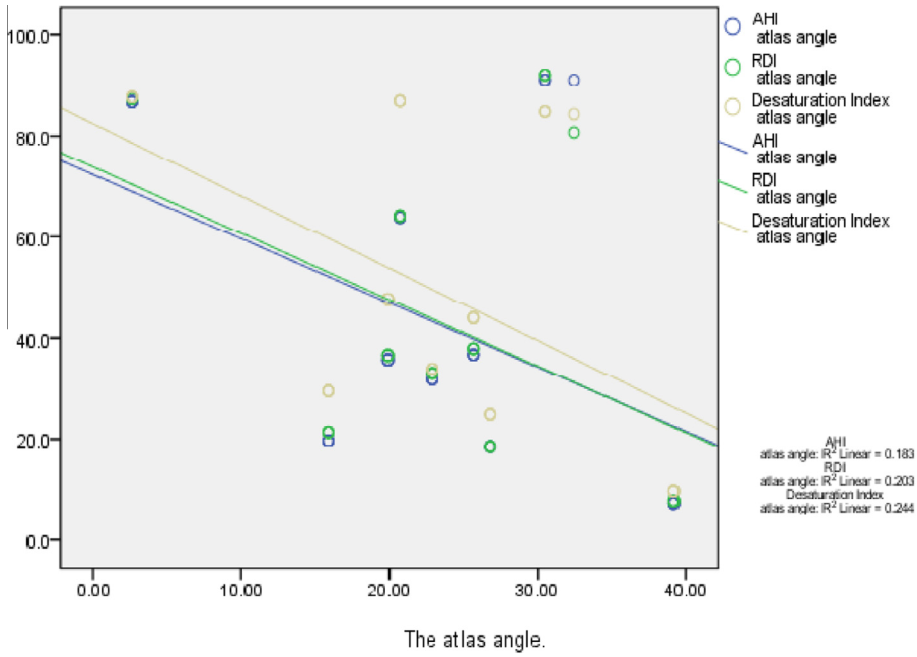


**Figure 1** Correlation between different OSAS severity scores and the atlas angle.

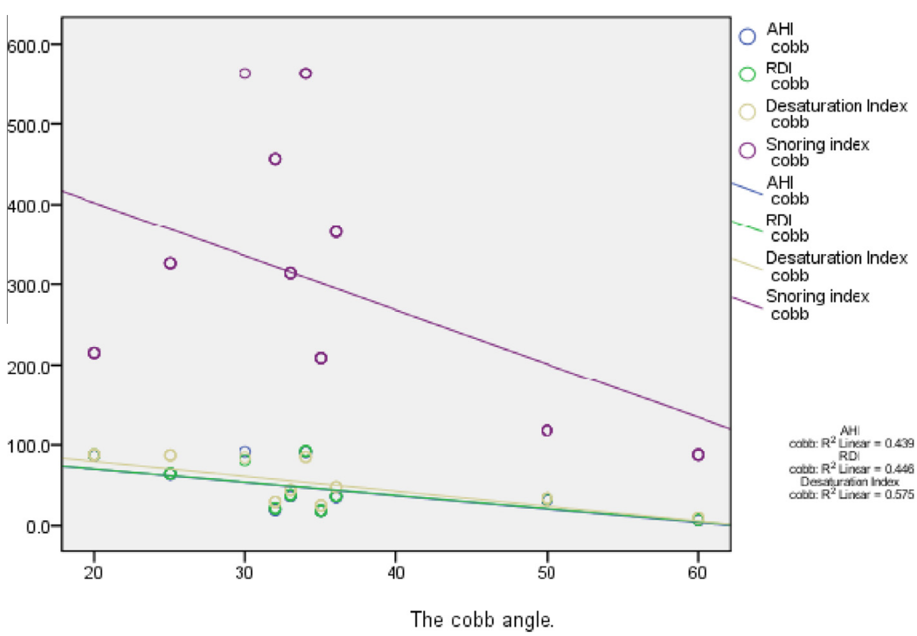


**Figure 2** Correlation between different OSAS severity scores and the Cobb angle of spinal lordosis.

the total variance for severity (measured as overall index) and 41% of the RDI positional dependency variance.

Despite variability, the anatomic region of the pharynx is the most common area of airway obstruction in OSAS patients [19]. The relationship between the atlas angle and severity was first postulated by one study [12]. The authors found that the atlas-occiput relationship is linked to the outflow of spinal nerves C1 and C2 and, therefore, that a vertebral misalignment at this level could negatively impact tone to the upper airway muscles innervated by these nerves, leading to muscular collapse of the upper airway during sleep [12].

The results showed significant associations between the Cobb angle of lordosis and gender and between the atlas angle and age (Table 3). One study [20] found that the spinal lordosis curve was more prevalent among males and individuals aged 45–65 years and that kyphotic cervical spines were more prevalent among females aged 18–44 years. Another study [21] reported that upon analysis of plain X-rays, many normal-appearing individuals exhibit a kyphotic cervical spine, especially if they depress their chins. One study [22] proposed that cervical spine flexion creates a state of tension and damage on the spinal cord and nerve roots and cranial nerves V–XII.

**Table 3** Significant correlations between the atlas angle and cervical Cobb angle with lordosis and the OSAS severity indices.

| | | Atlas angle | Cobb |
|---|---|---|---|
| Gender | R | −0.013 | 0.350 |
| | P | 0.939 | .037 |
| Age | R | −0.531 | −0.325 |
| | P | 0.001 | 0.053 |
| BMI | R | −0.760 | −0.774 |
| | P | 0.000 | .000 |
| AHI | R | −0.428 | −0.663 |
| | P | 0.009 | 0.000 |
| RDI | R | −0.450 | −0.668 |
| | P | 0.006 | 0.000 |
| Desaturation index | R | −0.494 | −0.759 |
| | P | 0.002 | 0.000 |
| Snoring index | R | −0.103 | −0.526 |
| | P | 0.550 | 0.0001 |
| Overall sleep apnea severity score | R | −0.465 | −0.717 |
| | P | 0.004 | 0.000 |
| RDI positional dependency | R | −0.405 | −0.634 |
| | P | 0.014 | 0.000 |
| Snoring positional dependency | R | −0.359 | −0.554 |
| | P | 0.032 | 0.000 |

**Table 4** Linear regression of cervical spine mechanics (Cobb angle of lordosis and Atlas angle) and the severity indices, and positional dependency.

| | Cobb angle of lordosis | | Atlas angle | |
|---|---|---|---|---|
| | Standardized coefficients beta | *p* | Standardized coefficients beta | *p* |
| AHI | −0.760 | 0.000 | 0.131 | 0.497 |
| RDI | −0.735 | 0.001 | −0.091 | 0.638 |
| Desaturation index | −0.862 | 0.000 | 0.141 | 0.401 |
| *Overall severity index | −0.818 | 0.000 | 0.137 | 0.445 |
| Snoring index | −0.983 | 0.000 | 0.620 | 0.003 |
| Snoring positional dependency | −0.634 | 0.006 | 0.108 | 0.616 |
| **RDI Positional dependency | −0.734 | 0.001 | 0.136 | 0.496 |

* $R^2 = 0.523$, $F = 18.072$, $p = 0.000$ for overall score.
** $R^2 = 0.411$, $F = 11.411$, $p = 0.000$ for RDI positional dependency.

Another study [23] suggested that sleep apnea is a mechano-pathophysiological condition involving respiratory mechanisms.

Therefore, one explanation of our results is misalignment of the upper cervical vertebrae with patho-mechanics that could restrict the flow of inspiration tone through the C1–C3 roots to some critical airway muscles, thereby promoting and/or aggravating OSAS.

Alternatively, altered cervical dynamics may be consequences rather than risk factors for OSAS. Adaptation may provide an alternative explanation to the association between spinal mechanics and the severity of OSAS in this study. OSAS patients frequently extend the head on a flexed neck while awake and maintain a characteristic under jut of the mandible relative to the maxilla to better open their airway [24,25]. Dobson et al. [12] suggested that this behavioral adaptation of the skull and cervical spine may be useful to expand the upper airway and enhance the flow of air to the awake patient but could exacerbate the collapse of the pharyngeal airway during sleep.

The main limitations to the validity of the results are the small size and cross-sectional design of the study and the absence of normal reference values for the cervical angles.

Despite these limitations, the results of this study are useful in understanding the pathophysiological bases for the severity of OSAS. These mechanisms may be amenable to intervention. Therefore, there is the potential for novel treatment strategies based on improving the cervical spine curve and angular rotation.

## Conclusions

The present study has attempted to describe the relationship between the Cobb angle and atlas angle patterns and severity and positional dependency in OSAS patients. There was a significant association between alterations in cervical spine mechanics, severity and positional dependency. Cervical lordosis, but not the atlas angle, was a significant negative predictor of severity and positional dependency. However, because of the small size and cross-sectional design of the study and the absence of normal reference values for these angles, more studies are required to validate the results and provide more information concerning the relationships between alterations in cervical spine mechanics and severity and positional dependency in OSAS patients. Further studies are also needed to study the possible beneficial effects of improving spinal curvature and angular rotation on severity and positional dependency in OSAS patients.

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